PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 510524 MSB/jal	**FOR FURTHER ACTION**	See Form PCT/IPEA/416
International application No. **PCT**/NZ2005/000011	International filing date *(day/month/year)* 7 February 2005	Priority date *(day/month/year)* 23 February 2004

International Patent Classification (IPC) or national classification and IPC

Int. Cl.

F02M 25/07 (2006.01) ***F02B 47/08*** (2006.01)

Applicant

SHUTTLEWORTH AXIAL MOTOR COMPANY LIMITED et al

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 3 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. [X] *(sent to the applicant and to the International Bureau)* a total of **11** sheets, as follows:
      - [ ] sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      - [ ] sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.

   b. [ ] *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or table related thereto, in electronic form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

[X]	Box No. I	Basis of the report
[ ]	Box No. II	Priority
[ ]	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
[ ]	Box No. IV	Lack of unity of invention
[X]	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
[ ]	Box No. VI	Certain documents cited
[ ]	Box No. VII	Certain defects in the international application
[ ]	Box No. VIII	Certain observations on the international application

Date of submission of the demand 28 November 2005	Date of completion of this report 13 April 2006
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer **ASANKA PERERA** Telephone No. (02) 6283 2373

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/NZ2005/000011

Box No. I Basis of the report

1. With regard to the **language,** this report is based on:

[X] The international application in the language in which it was filed

[ ] A translation of the international application into , which is the language of a translation furnished for the purposes of:

[ ] international search (under Rules 12.3(a) and 23.1 (b))

[ ] publication of the international application (under Rule 12.4(a))

[ ] international preliminary examination (Rules 55.2(a) and/or 55.3(a))

2. With regard to the **elements** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

[ ] the international application as originally filed/furnished

[X] the description:

pages **1, 7-20** as originally filed/furnished
pages* **2-6** received by this Authority on **28 November 2005** with the letter of **28 November 2005**
pages* received by this Authority on with the letter of

[X] the claims:

pages as originally filed/furnished
pages* as amended (together with any statement) under Article 19
pages* **21-26** received by this Authority on **28 November 2005** with the letter of **28 November 2005**
pages* received by this Authority on with the letter of

[X] the drawings:

pages **1/7-7/7** as originally filed/furnished
pages* received by this Authority on with the letter of
pages* received by this Authority on with the letter of

[ ] a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing.

3. [ ] The amendments have resulted in the cancellation of:

[ ] the description, pages
[ ] the claims, Nos.
[ ] the drawings, sheets/figs
[ ] the sequence listing *(specify)*:
[ ] any table(s) related to the sequence listing *(specify)*:

4. [ ] This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

[ ] the description, pages
[ ] the claims, Nos.
[ ] the drawings, sheets/figs
[ ] the sequence listing *(specify)*:
[ ] any table(s) related to the sequence listing *(specify)*:

* *If item 4 applies, some or all of those sheets may be marked "superseded."*

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/NZ2005/000011

Box No. V **Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	**1-34**	**YES**
	Claims		**NO**
Inventive step (IS)	Claims	**1-34**	**YES**
	Claims		**NO**
Industrial applicability (IA)	Claims	**1-34**	**YES**
	Claims		**NO**

2. Citations and explanations (Rule 70.7)

The prior art cited in the International Search Report do not anticipate the subject matter of the above claims.

Therefore the subject matter of these claims is new and meets the requirements of Article 33(2) PCT with regard to novelty.

The claimed invention is not obvious in the light of any of the cited documents nor is it disclosed in any obvious combination of them. It is also considered that it would not be obvious to a person skilled in the art in the light of common general knowledge either by itself or in combination with any of these documents.

Therefore the subject matter of these claims is not obvious and meets the requirements of Article 33(3) PCT with regard to inventive step.

piston and a power cylinder containing a power piston. The compression piston performs the intake and compression strokes of a four stroke cycle, and the power piston performs the power and exhaust strokes of the same four stroke cycle. A fresh air/fuel mixture is compressed in the compression cylinder and is delivered via a gas passage to the combustion cylinder for combustion, and then exhausted from the engine. The two pistons are provided so that the power piston can be offset to align the maximum combustion pressure with the maximum torque applied to the crank shaft, and so that the compression piston can be offset to align the maximum compression with the maximum torque applied from the crank shaft. The Scuderi systems do not address compression ratio issues. Only fresh compressed mixture is shared between cylinders.

It is an object of the present invention to provide a recirculation system for a motor which is operable to improve combustion properties and improve performance and/or which at least provides the public with a useful choice.

SUMMARY OF THE INVENTION

In accordance with a first aspect of the present invention, there is provided a motor comprising: an engine block with three or more cylinders arranged to fire with a firing order; a fuel injector associated with each cylinder; and a recirculation system comprising fluid transfer paths which are arranged to provide a fluid connection between cylinders sequentially in the firing order of the motor, the motor configured such that combustion in a cylinder creates a combusted mixture having a combustion pressure, which combustion pressure forces some of that combusted mixture to at least partly mix with fuel for the next cylinder in the firing order to improve the combustion properties of the fuel, and to deliver a mixture of the combusted mixture and fuel under elevated temperature and pressure into said next cylinder in the firing order.

It should be noted that where reference herein is made to "combusted mixture under combustion temperature and pressure", that need not mean that the temperature and pressure will be at the same levels as at the time of combustion, as pressure and temperature losses will occur during transfer of the mixture. However, the mixture will be at a significantly elevated temperature and pressure relative to any combustible mixture in the next cylinder in the firing order.

The term 'comprising' as used in this specification and claims means 'consisting at least in part of', that is to say when interpreting statements in this specification and claims which include that term, the features prefaced by that term in each statement all need to be present but other features can also be present.

In one embodiment, each cylinder has an injector body associated therewith, with each injector body having an internal chamber in communication with a fuel inlet port for delivering fuel into the internal chamber, a fuel outlet port for delivering fuel under pressure from the chamber into the associated cylinder, a mixture inlet port and a mixture outlet port, with the mixture inlet port of each injector body in fluid communication with the mixture outlet port of an injector body associated with the immediately preceding cylinder in the firing order of the motor, the motor configured to deliver combusted mixture under combustion pressure and temperature from an outlet port of an injector body associated with a cylinder that has just fired to an inlet port of an injector body associated with the next cylinder in the firing order of the motor to at least partly mix with fuel in the internal chamber of the injector body associated with said next cylinder in the firing order to improve the combustion properties of the fuel.

The fuel inlet port of each injector body is preferably configured for receipt of a respective fuel injector.

Advantageously, each mixture inlet port comprises a non-return valve which allows the mixture to travel into the internal chamber through the port but not out of the internal chamber through the port.

Preferably, each mixture outlet port comprises a non-return valve which allows mixture to travel out of the internal chamber through the port but not into the internal chamber through the port.

Suitably, each fuel inlet port comprises a non-return valve which allows fuel to flow into the internal chamber through the fuel inlet port, but not out of the internal chamber through the fuel inlet port.

Transfer paths are preferably provided to fluidly connect the mixture outlet port of each injector body with the mixture inlet port of the injector body associated with the next cylinder in the firing order. The transfer paths may be pipes, tubes, or the like.

In an alternative embodiment, the recirculation system is arranged substantially internally within a cylinder head of the motor. Preferably, the cylinder head comprises a pre-mix chamber is associated with each cylinder, and the cylinder head includes transfer paths configured to deliver combusted mixture under combustion pressure and temperature from the pre-mix chamber associated with a cylinder that has just fired to the pre-mix chamber associated with the next cylinder in the firing order. Preferably, each transfer path comprises at least one non-return valve configured to allow combusted mixture under combustion pressure and temperature to be delivered to the pre-mix chamber associated with the next cylinder in the firing order.

It is preferred that a fluid path is provided between each pre-mix chamber and the respective cylinder, and preferably the fluid path includes a nozzle to deliver mixture for combustion into the respective cylinder under pressure.

The motor may be an inline, "V", or horizontally opposed ("boxer") configuration two- or four-stroke internal combustion motor. Alternatively, the motor may be a two- or four-stroke axial motor. The system could also be used with a rotary engine.

In the two-stroke embodiment, the motor is preferably configured such that the combusted mixture is delivered to at least partly mix with the fuel for the next cylinder in the firing order as the piston in said next cylinder is nearing the top of its compression stroke. Preferably, the motor is configured such that when a cylinder is on its compression stroke, some uncombusted air/fuel mixture is delivered under relatively low pressure to the next cylinder in the firing order as said next cylinder is undergoing its compression stroke.

In a preferred embodiment the motor is configured to deliver some uncombusted mixture from a cylinder as its piston is undergoing a compression stroke to a fluid transfer path which provides a fluid connection between that cylinder and the following cylinder in the firing order, such that when combustion occurs in the cylinder, the combusted mixture from

that cylinder forces the uncombusted mixture from the transfer path to mix with fuel for the next cylinder in the firing order.

In accordance with a second aspect of the present invention, there is provided a recirculation system for a motor having three or more cylinders arranged to fire with a firing order, comprising: a plurality of fuel injector bodies, each injector body having an internal chamber in communication with a fuel inlet port for delivering fuel into the internal chamber, a fuel outlet port for delivering fuel under pressure into an associated cylinder, a mixture inlet port and a mixture outlet port, and arranged with the mixture inlet port of each injector body in fluid communication with the mixture outlet port of an injector body associated with the immediately preceding cylinder in the firing order of the motor; the recirculation system configured to deliver combusted mixture from an outlet port of an injector body associated with a cylinder that has just fired to an inlet port of the injector body associated with the next cylinder in the firing order to at least partly mix with fuel in the internal chamber of that next injector body to improve the combustion properties of the fuel, and to deliver a mixture of the combusted mixture and fuel under elevated temperature and pressure from the fuel outlet port of said injector body associated with the next cylinder in the firing order.

The fuel inlet port of each injector body may be configured for receipt of a respective fuel injector.

Preferably, each mixture inlet port comprises a non-return valve which allows the mixture to travel into the internal chamber through the port but not out of the internal chamber through the port.

Preferably, each mixture outlet port comprises a non-return valve which allows mixture to travel out of the internal chamber through the port but not into the internal chamber through the port.

Each fuel inlet port may comprise a non-return valve which allows fuel to flow into the internal chamber through the fuel inlet port, but not out of the internal chamber through the fuel inlet port.

Preferably, the mixture outlet port of each injector body is fluidly connected to the mixture inlet port of the injector body associated with the next cylinder in the firing order of the motor by a transfer path. Each transfer path may comprise a pipe or tube.

The recirculation system is preferably configured such that the combusted mixture at least partly atomises the fuel in the internal chamber to which the combusted mixture has been delivered under combustion pressure and temperature.

In accordance with a third aspect of the present invention, there is provided a method of enhancing combustion in a motor having an engine block with at least three cylinders arranged to fire with a firing order, and a fuel injector associated with each cylinder, comprising delivering combusted mixture under combustion pressure and temperature from a cylinder which has just fired to at least partly mix with fuel for the next cylinder in the firing order to improve the combustion properties of the fuel, and delivering a mixture of the combusted mixture and fuel under elevated temperature and pressure from the fuel outlet port of said injector body associated with the next cylinder in the firing order.

Preferably, each cylinder has an injector body associated therewith, with each injector body having an internal chamber in communication with a fuel inlet port for delivering fuel into the internal chamber, a fuel outlet port for delivering fuel under pressure from the chamber into the associated cylinder, a mixture inlet port and a mixture outlet port, with the mixture inlet port of each injector body in fluid communication with the mixture outlet port of an injector body associated with the immediately preceding cylinder in the firing order of the motor; and wherein the method comprises delivering combusted mixture under combustion pressure and temperature from an outlet port of an injector body associated with a cylinder that has just fired to an inlet port of an injector body associated with the next cylinder in the firing order of the motor to at least partly mix with fuel in the internal chamber of that adjacent injector to improve the combustion properties of the fuel.

Transfer paths may be provided to link the mixture outlet port of each injector body with the mixture inlet port of the injector body associated with the next cylinder in the firing

CLAIMS

1. A motor comprising: an engine block with a three or more cylinders arranged to fire with a firing order; a fuel injector associated with each cylinder; and a recirculation system comprising fluid transfer paths which are arranged to provide a fluid connection between cylinders sequentially in the firing order of the motor, the motor configured such that combustion in a cylinder creates a combusted mixture having a combustion pressure, which combustion pressure forces some of that combusted mixture to at least partly mix with fuel for the next cylinder in the firing order to improve the combustion properties of the fuel, and to deliver a mixture of the combusted mixture and fuel under elevated temperature and pressure into said next cylinder in the firing order.

2. A motor as claimed in claim 1, wherein each cylinder has an injector body associated therewith, with each injector body having an internal chamber in communication with a fuel inlet port for delivering fuel into the internal chamber, a fuel outlet port for delivering fuel under pressure from the chamber into the associated cylinder, a mixture inlet port and a mixture outlet port, with the mixture inlet port of each injector body in fluid communication with the mixture outlet port of an injector body associated with the immediately preceding cylinder in the firing order of the motor, the motor configured to deliver combusted mixture under combustion pressure and temperature from an outlet port of an injector body associated with a cylinder that has just fired to an inlet port of an injector body associated with the next cylinder in the firing order of the motor to at least partly mix with fuel in the internal chamber of the injector body associated with said next cylinder in the firing order to improve the combustion properties of the fuel.

3. A motor as claimed in claim 2, wherein the fuel inlet port of each injector body is configured for receipt of a respective fuel injector.

4. A motor as claimed in claim 2 or claim 3, wherein each mixture inlet port comprises a non-return valve which allows the mixture to travel into the internal chamber through the port but not out of the internal chamber through the port.

5. A motor as claimed in any one of claims 2 to 4, wherein each mixture outlet port comprises a non-return valve which allows mixture to travel out of the internal chamber through the port but not into the internal chamber through the port.

6. A motor as claimed in any one of claims 2 to 5, wherein each fuel inlet port comprises a non-return valve which allows fuel to flow into the internal chamber through the fuel inlet port, but not out of the internal chamber through the fuel inlet port.

7. A motor as claimed in any one of claims 2 to 6, wherein transfer paths are provided to fluidly connect the mixture inlet port of each injector body with the mixture outlet port of the injector body associated with the immediately preceding cylinder in the firing order.

8. A motor as claimed in claim 7, wherein the transfer paths comprise pipes or tubes.

9. A motor as claimed in claim 1, wherein the recirculation system is arranged substantially internally within a cylinder head of the motor.

10. A motor as claimed in claim 9, wherein the cylinder head comprises a pre-mix chamber associated with each cylinder, and the cylinder head includes transfer paths configured to deliver combusted mixture under combustion pressure and temperature from the pre-mix chamber associated with a cylinder that has just fired to the pre-mix chamber associated with the next cylinder in the firing order.

11. A motor as claimed in claim 10, wherein each transfer path comprises at least one non-return valve configured to allow combusted mixture under combustion pressure and temperature to be delivered to the pre-mix chamber associated with the next cylinder in the firing order.

12. A motor as claimed in claim 10 or 11, wherein a fluid path is provided between each pre-mix chamber and the respective cylinder.

13. A motor as claimed in claim 12, wherein each fluid path comprises a nozzle to deliver mixture for combustion into the respective cylinder under pressure.

14. A motor as claimed in any one of the preceding claims, wherein the motor is configured to operate in a two-stroke configuration, and wherein the motor is configured such that the combusted mixture is delivered to at least partly mix with the fuel for the next cylinder in the firing order as the piston in said next cylinder is nearing the top of its compression stroke.

15. A motor as claimed in claim 14, wherein the motor is configured such that when a cylinder is on its compression stroke, some uncombusted air/fuel mixture is delivered under relatively low pressure to the next cylinder in the firing order as said next cylinder is undergoing its compression stroke.

16. A motor as claimed in any one of the preceding claims, configured to deliver some uncombusted mixture from a cylinder as its piston is undergoing a compression stroke to a fluid transfer path which provides a fluid connection between that cylinder and the following cylinder in the firing order, such that when combustion occurs in the cylinder, the combusted mixture from that cylinder forces the uncombusted mixture from the transfer path to mix with fuel for the next cylinder in the firing order.

17. A motor as claimed in any one of the preceding claims, wherein the motor is an axial motor.

18. A recirculation system for a motor having three or more cylinders arranged to fire with a firing order, comprising: a plurality of fuel injector bodies, each injector body having an internal chamber in communication with a fuel inlet port for delivering fuel into the internal chamber, a fuel outlet port for delivering fuel under pressure into an associated cylinder, a mixture inlet port and a mixture outlet port, and arranged with the mixture inlet port of each injector body in fluid communication with the mixture outlet port of an injector body associated with the immediately preceding cylinder in the firing order of the motor; the recirculation system configured to deliver combusted mixture from an outlet port of an injector body associated with a cylinder that has just fired to an inlet port of the injector body associated with the next cylinder in the firing order to at least partly mix with fuel in the internal chamber of that next injector body to improve the combustion properties of the fuel, and to deliver a mixture of the combusted mixture and fuel under elevated temperature

and pressure from the fuel outlet port of said injector body associated with the next cylinder in the firing order.

19. A recirculation system as claimed in claim 18, wherein the fuel inlet port of each injector body is configured for receipt of a respective fuel injector.

20. A recirculation system as claimed in claim 18 or 19, wherein each mixture inlet port comprises a non-return valve which allows the mixture to travel into the internal chamber through the port but not out of the internal chamber through the port.

21. A recirculation system as claimed in any one of claims 18 to 20, wherein each mixture outlet port comprises a non-return valve which allows mixture to travel out of the internal chamber through the port but not into the internal chamber through the port.

22. A recirculation system as claimed in any one of claims 18 to 21, wherein each fuel inlet port comprises a non-return valve which allows fuel to flow into the internal chamber through the fuel inlet port, but not out of the internal chamber through the fuel inlet port.

23. A recirculation system as claimed in any one of claims 18 to 21, wherein the mixture outlet port of each injector body is fluidly connected to the mixture inlet port of the injector body associated with the next cylinder in the firing order of the motor by a transfer path.

24. A recirculation system as claimed in claim 23, wherein each transfer path comprises a pipe or tube.

25. A recirculation system as claimed in any one of claims 18 to 24, configured such that the combusted mixture at least partly atomises the fuel in the internal chamber to which the combusted mixture has been delivered under combustion pressure and temperature.

26. A method of enhancing combustion in a motor having an engine block with at least three cylinders arranged to fire with a firing order, and a fuel injector associated with each cylinder, comprising delivering combusted mixture under combustion pressure and temperature from a cylinder which has just fired to at least partly mix with fuel for the next cylinder in the firing order to improve the combustion properties of the fuel, and delivering

a mixture of the combusted mixture and fuel under elevated temperature and pressure into said next cylinder in the firing order.

27. A method as claimed in claim 26, wherein each cylinder has an injector body associated therewith, with each injector body having an internal chamber in communication with a fuel inlet port for delivering fuel into the internal chamber, a fuel outlet port for delivering fuel under pressure from the chamber into the associated cylinder, a mixture inlet port and a mixture outlet port, with the mixture inlet port of each injector body in fluid communication with the mixture outlet port of an injector body associated with the immediately preceding cylinder in the firing order of the motor; and wherein the method comprises delivering combusted mixture under combustion pressure and temperature from an outlet port of an injector body associated with a cylinder that has just fired to an inlet port of an injector body associated with the next cylinder in the firing order of the motor to at least partly mix with fuel in the internal chamber of that adjacent injector to improve the combustion properties of the fuel.

28. A method as claimed in claim 27, wherein transfer paths are provided to link the mixture outlet port of each injector body with the mixture inlet port of the injector body associated with the next cylinder in the firing order, and the step of delivering combusted mixture under combustion pressure and temperature from an outlet port of an injector body associated with a cylinder that has just fired to an inlet port of an injector body associated with the next cylinder in the firing order of the motor, comprises transferring the combusted mixture via the respective transfer path.

29. A method as claimed in claim 26, wherein the recirculation occurs internally within a cylinder head of the motor.

30. A method as claimed in claim 29, wherein a pre-mix chamber is associated with each cylinder, and the method comprises delivering combusted mixture under combustion pressure and temperature from the pre-mix chamber associated with a cylinder that has just fired to the pre-mix chamber associated with the next cylinder in the firing order.

31. A method as claimed in claim 30, comprising delivering mixture for combustion from each pre-mix chamber into the respective cylinder under pressure.

32. A method as claimed in any one of claims 26 to 31, wherein the motor is configured to operate in a two-stroke configuration, and the step of delivering combusted mixture under combustion pressure and temperature from a cylinder which has just fired to at least partly mix with fuel for the next cylinder in the firing order occurs as the piston in said next cylinder is nearing the top of its compression stroke.

33. A method as claimed in claim 32, comprising delivering from a cylinder on its compression stroke some uncombusted air/fuel mixture under relatively low pressure to the next cylinder in the firing order as said next cylinder is undergoing its compression stroke.

34. A method as claimed in any one of claims 26 to 33, comprising delivering some uncombusted mixture from a cylinder as its piston is undergoing a compression stroke to a fluid transfer path which provides a fluid connection between that cylinder and the following cylinder in the firing order, such that when combustion occurs in the cylinder, the combusted mixture from that cylinder forces the uncombusted mixture from the transfer path to mix with fuel for the next cylinder in the firing order.